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MECHANICAL PATTERNING OF A DEVICE LAYER

Field of the Invention

The present invention relates to the fabrication of devices. More particularly, the invention relates to patterning of a device layer on a substrate.

Background of the Invention

In device fabrication, one or more device layers are formed on a substrate. The layers are sequentially deposited and patterned to create features on the surface of the substrate. The layers can be patterned individually and/or as a combination of layers to form the desired features. The features serve as components that perform the desired functions, creating the device.

One type of device which is of particular interest is a light emitting diode (LED). Typically, an LED cell or pixel comprises one or more functional layers sandwiched between two electrodes to form a functional stack. Charge carriers are injected from both electrodes. These charge carriers recombine in the functional layer or layers, causing visible radiation to emit. Recently, significant advances have been made utilizing organic functional layers to form organic LEDs

(OLEDs). Such devices are fabricated on rigid glass substrates having a thickness of about 0.3-1.1 mm.

Typically, OLED devices comprises a plurality of OLED pixels arranged to form a display, such as a flat panel display (FPD). A pixelated OLED device includes, for example, a plurality of first electrode strips formed on the substrate. The strips are arranged in a first direction. One of more organic layers are formed on the first electrodes strips. A plurality of second electrode strips is formed over the organic layers in a second direction. Typically, the first and second electrode strips are orthogonal to each other. The intersections of the first and second electrode strips form LED pixels.

The first electrode strips are created on the substrate by patterning an electrode layer. Conventionally, the electrode layer is patterned by photolithographic and etch processes. For example, a photosensitive resist layer is deposited on the electrode. The resist layer is exposed with radiation having the desired pattern defined by a mask. After development, unwanted resist is removed to expose portions of the electrode beneath. The exposed portions are removed by a wet etch, leaving the desired pattern

on the electrode layer. Thus, conventional techniques for patterning the electrode require numerous steps, increasing raw process time and manufacturing cost.

As evidenced by the above discussion, it is desirable to provide a simplified process of patterning a device layer.

Summary of the Invention

The invention relates to patterning a device layer on a substrate during device fabrication. In accordance with the invention, the patterning of the device layer is achieved using a stamp with a pattern thereon. The pattern is formed by protrusions having a height greater than the thickness of the device layer to pattern the device layer. The stamp is pressed against the surface of the substrate under a load which patterns the device layer. The load is selected to precisely control cracking the edges of the patterned areas but without cracking the non-patterned areas.

Brief Description of the Drawings

Fig. 1 shows an organic pixel LED;

Figs. 2-4 show a process for patterning a device layer in accordance with one embodiment of the invention; and

Fig. 5 shows an alternative process for patterning a device layer.

Preferred Embodiments of the Invention

The invention relates generally to the fabrication of devices. In particular, the invention describes a process for patterning a device layer on a substrate, particularly a device layer formed on a ductile or flexible substrate. Various types of devices can be formed by the present invention. For example, electrical, mechanical, or electromechanical devices can be formed. Also, the invention can be useful in fabricating a microelectromechanical system (MEMS). In one embodiment, a process for forming a pixelated organic LED device is provided.

Fig. 1 shows a cross-section of an OLED pixel. As shown, a substrate 101 is provided. The substrate provides support for the LED pixel. A functional stack 105 comprising of one or more organic functional layers 120 formed between conductive layers 110 and 150 is formed on the substrate, creating the LED pixel. The

conductive layer 110 serves as an anode and the conductive layer 150 serves as a cathode.

A plurality of LED pixels can be arranged on the substrate to form an FPD. The FPD is used in various consumer electronic products, including cellular phones, cellular smart phones, personal organizers, pagers, advertising panel, touch screen displays, teleconferencing equipment, multimedia equipment, virtual reality products, and display kiosks.

Figs. 2-5 show a process for patterning a device layer on a substrate in the fabrication of a device. In one embodiment, the device fabricated comprises a pixelated OLED device. Forming other types of devices such as electrical and/or mechanical devices, including sensor arrays, is also useful.

Referring to Fig. 2, a substrate 201 is provided on which the active components of the device are formed. The substrate comprises a plastic or a polymeric material. In one embodiment, the substrate comprises a flexible substrate, such as poly(ethylene terephthalate) (PET) or polyester for forming flexible devices. The substrate can comprise a transparent substrate to serve as, for example, a display surface for an OLED display. The use of a flexible transparent substrate for forming

a flexible display is also useful. Various types of plastic substrates, such as PET, poly(butylene terephthalate) (PBT), poly(enthylene naphthalate) (PEN), Polycarbonate (PC), polyimides (PI), polysulfones (PSO), and poly(*p*-phenylene ether sulfone) (PES) are useful. Other substrates comprising polyethylene (PE), polypropylene (PP), poly(vinyl chloride) (PVC), polystyrene (PS) and poly(methyl methyleacrylate) (PMMA), can also be used.

In one embodiment, the substrate should be thin to result in a thin device while providing sufficient mechanical integrity during the fabrication process to support the active components. Preferably, the substrate should be as thin as possible while providing sufficient mechanical integrity during the fabrication process. The substrate thickness is, for example, about 20 - 200 um. Thicker substrates are also useful. For example, thicker substrate, can be used where device thickness or flexibility is not an issue.

A device layer 210 is formed on the substrate. The device layer comprises, for example, a conductive layer. Other types of device layers, such as dielectrics or semiconductors, are also useful. In one embodiment the device layer comprises a transparent

conductive layer that serves as an electrode for an LED device. The transparent conductive layer comprises an indium-tin-oxide (ITO). ITO is useful in forming the transparent anode of the LED device. Other transparent conductive layers, including zinc-oxide or indium-zinc-oxide are also useful. Various techniques, such as sputtering, physical vapor deposition (PVD), chemical vapor deposition (CVD) or plasma enhanced CVD (PECVD) can be employed to form the device layer. The device layer is deposited on the substrate to a thickness of about, for example, 100 nm. The thickness, of course, can vary depending on design requirements.

A stamp 280 comprising a desired pattern on a surface 231 is provided. The pattern is define by protrusions 285 on surface 231. The stamp is made of a hard material such as steel, silicon, or ceramic. Other materials that are sufficiently hard can also be used to form the stamp.

In one embodiment, the pattern is deeper than the thickness of the device layer. This ensures proper patterning of the device layer. However, the height of the protrusions should be less than that which would compromise the support function of the substrate. In one embodiment, the height of the protrusions is at

least about 2 - 10 times the thickness of the device layer, preferably 5 - 10 times the thickness of the device layer. For example, the height of the protrusions is about 0.5 - 1 µm for a 100 mm thick device layer. The height of the protrusions can be optimized according to the mechanical properties and thickness of the substrate.

Referring to Fig. 3, a load is applied on the stamp 280, forcing the stamp against the substrate 201. This causes the pattern on the stamp to be transferred to the substrate. The load applied on the stamp is sufficient to prevent the device layer 210 from cracking in the active or non-patterned areas as it is patterned. In one embodiment, the net pressure of the load is about 200 - 400 MPa for a typical polymer substrate. In general, the required net pressure should exceed about 1.1 times the yield strength of the substrate material.

Referring to Fig. 4, the stamp is lifted from the substrate. As shown, the pattern on the stamp is transferred onto the device layer. In one embodiment, the device layer is patterned to form electrode strips on the substrate. Conventional processing continues to form the device.

In one embodiment, the process continues to fabricate OLED pixels of an OLED device. Fabrication of OLED pixels is described in, for example, United States Patent 4,720,432 and Burroughes et. al, Nature 347 (1990) 539, which are herein incorporated by reference for all purposes. This includes, for example, depositing one or more organic functional layers, such as conjugated polymer or Alq_3, on the electrode. Other types of organic layers can also be useful. Preferably, a plurality of functional layers is formed on the electrode. Second electrode strips comprising metal such as aluminum or other conductive material are formed over the functional layer. The second electrode strips are typically orthogonal to the bottom electrode strips. Providing second electrode strips that are diagonal to the bottom electrode strips is also useful. The intersections of the top and bottom electrode strips form OLED pixels. Various techniques can be used to form the electrode strips. For example, the second electrode strips can be formed by selective deposition techniques. Alternatively, the electrode strip can be formed by selectively patterning a top electrode layer to form the strips.

In an alternative embodiment, the pattern on the stamp can be formed to include a plurality of devices for parallel processing, thereby decreasing process time per device. The stamp pattern can be formed by a variety of techniques. Such techniques include, for example, grinding or photolithographic and etch processes.

Fig. 5 shows another embodiment of the invention. As shown, a stamp comprising a drum 580 with the desired pattern 585 thereon is provided. The drum stamp is used in reel-to-reel processing. A long flexible substrate 501 with a device layer 510 formed thereon is provided. The substrate is translated through the drum while it is pressed under rotation, patterning the device layer. As shown, the substrate is translated in a direction from right to left and the drum stamp is rotated in the clockwise direction. Reversing the direction that the substrate is translated is also useful. Reel-to-reel processing enables parallel processing of devices.

While the invention has been particularly shown and described with reference to various embodiments, it will be recognized by those skilled in the art that modifications and changes may be made to the present invention without departing from the spirit and scope

thereof. The scope of the invention should therefore be determined not with reference to the above description but with reference to the appended claims along with their full scope of equivalents.

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